THE GLOSTEN ASSOCIATES
Consulting Engineers Serving the Marine Community

Study of Tug Escort for Laden Tankers Final Presentation

Presented to The Department of Ecology Spills Program
Oil Spill Advisory Committee
8 December 2004

Outline of Presentation

1. INTRODUCTION – Scope of Work
2. RCW 88.16.190 (Repeat)
   - Issues with RCW 88.16.190
3. OPA 90 (Repeat)
   - Phase-out of Single hull Tankers and the Expiration of OPA 90
4. Basis for Acceptable Risk
5. Draft Recommendations
   - Consequence of Recommendations
6. Discussion of Findings
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   - Incident Probabilities
   - Socioeconomic costs
   - Human factors in Tug Escort Emergency Response
   - Additional Services of Escort Tugs; Auxiliary Bridge, Scouting, Firefighting
   - Oil Outflow and loading to 125,000 dwt
   - Risk Introduced
7. Recommendations for Further Study

Comments, Additions, Edits and Corrections resulting from the 8 December presentation are highlighted in yellow.

David Gray, Colin Moore
Martha Grabowski
Dagmar Etkin
The Glosten Associates, Inc 8 December 2004

Introduction - Project Team

The Glosten Associates — **Seattle, WA**

- 54 Associates, including 25 P.E.'s and 2 Ph.D.'s
- David L. Gray, P.E., Senior Principal
- Bruce L. Hutchison, P.E., Senior Principal
- Duane H. Laible P.E., Chairman Senior Principal
- S. Anil Kumar, Ph.D., Analyst
- Charles J. Nordstrom, Naval Architect
- William L. Moon, Naval Architect
- Other contributors

Herbert Engineering Corporation — **Alameda, CA**

- 20 engineers including 8 PE's & 2 PhD's
- Colin Moore, Ph.D., Principal
- Keith Michel, P.E., President

Prof. Martha R. Grabowski, Ph.D. — **Syracuse, NY**

Environmental Research Consulting — **Cortlandt Manor, NY**

- Dagmar S. Etkin, Ph.D.

Introduction - Areas of Expertise

Glosten

Tanker escort plans prepared in conjunction with The Glosten Associates:

- Puget Sound Escort Plan
- San Francisco Bay Area Escort Plan
- Long Beach, California Escort Plan
- Prince William Sound Escort Plan

Design of escort tugs (Puget Sound and Newfoundland, Canada)

Herbert

- Double-hull tanker design
- IMO regulation development
- Evaluation of environmental performance of alternative tanker designs
- Numerous probabilistic oil outflow studies
- Neah Bay rescue tug study

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Introduction - Areas of Expertise

Environmental Research Consulting – Dagmar S. Etkin, Ph.D.

Select Research and Consulting Projects

"Analysis of Oil Spill Risk From Potentially Polluting Shipwrecks"
(2005 International Oil Spill Conference Committee): 2004 – 2005

"Oil Spill Response, Socioeconomic, and Environmental Cost-Benefit Analysis"
(Washington Department of Ecology): 2003 – present

"Cost-Benefit Analysis of US EPA Oil Program"
(US EPA subcontract to Abt Associates): 2002 – present

"Development of Model to Estimate Costs and Damages From Oil Spills"
(US EPA subcontract to Abt Associates): 2002 – present

Introduction - Areas of Expertise

Dr. Martha Grabowski

Select Research and Consulting Projects

“Leading Safety Indicators of Risk in Marine Transportation”

“St. Lawrence Seaway AIS Performance Impact Study”

“Distributed Mobile Collaborative Networks”

“Shipboard Display of Automatic Identification Systems Information”

“Risk Analysis of California-Federal Water Quality an Reliability”

“Risk Evaluation of Passenger Vessel Operations”

“Evaluation of Maritime Risk: Port of Houston”

“Evaluating and Monitoring Maritime Risk: Prince William Sound, Alaska”

“Human Factors in Maritime Shipping”

Introduction – Scope of Work

- Describe the present tug escort requirements as stated in the Washington State Pilotage Act.
- Describe how tankers are currently escorted in the subject waters.
- Describe the environmental and economic values potentially protected by the current escort system.
- Describe the capabilities and limitations of double-hulled, single-propulsion tankers (and their escort tugs) that presently call in the subject waters.
- Describe the phase-out of single-hull tankers and the anticipated change in the use of tank barges and articulated tug-and-barge vessels.
- Describe the safety enhancements of the new double-hull tankers deployed with redundant systems that presently call in the subject waters.

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Introduction – Scope of Work

- Describe the range of technological, human, and external factors that influence risk management as it applies to the tug escort system.
- Compare Washington State Pilotage Act and current Puget Sound practice to other tug escort systems in place in other parts of the country and across the world.
- Identify any effects of proposed changes to the tug escort system on the population of capable tugs in Puget Sound.
- Prepare a report of findings and making recommendations for escorting the new double-hulled tankers with redundant systems in the subject waters.
- Prepare an analysis of the anticipated safety, environmental, and economic consequences of the draft recommendations.

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History of Tanker Escort Regulations

Year	Regulation
1969	International Convention on Oil Pollution Prevention
1971	IMO Amendments to OILPOL 1954
1972	Ports and Waterways Safety Act
1972	Federal Water Pollution Control Act
1973	1973 MARPOL Convention
1975	RCW 88.16.190
1978	MARPOL 73/78
1978	Port and Tanker Safety Act
1990	Oil Pollution Act 1990
1992	Amendments to MARPOL 73/78 (Regulations 13F and 13G)
1994	RCW 88.16.190 Amendment
1999	Amendments to Regulation 13G
2001	Accelerated Phase-Out of Single-Hull Tankers
2003	Accelerated Phase-Out of Pre-MARPOL Tankers

Year	Select Oil Spill
1967	Torrey Canyon (119,000 MT)
1974	Metula (57,800 MT)
1978	Amoco Cadiz (223,000 MT)
1979	Atlantic Empress (287,000 MT)
1984	Mobil Oil (700 MT)
1985	Arco Anchorage (830 MT)
1989	Exxon Valdez (38,000 MT)
1992	Aegean Sea (74,000 MT)
1993	Braer (85,000 MT)
1996	Sea Empress (72,000 MT)
1999	Erika (15,000 MT)
2002	Prestige (77,000 MT)

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RCW 88.16.190

Regulations entered force in 1975 (last amended 1994):

1. Oil tankers > 125,000 DWT prohibited beyond east of line from Discovery Island light south to New Dungeness light
2. Oil tankers of 40,000 to 125,000 DWT required to have all of the following standard safety features (minimum compliance), to proceed east of above line:
   - Shaft horsepower ratio of 1 hp to each 2-½ dwt (*50,000 hp for 125,000 dwt*)
   - Twin screws
   - Double bottoms underneath all oil and liquid cargo compartments
   - Two radars (one a collision avoidance radar) in working order & operating
   - Other navigational aids as prescribed by board of pilotage commissioners

OR:

Transit in ballast or under escort of tug(s) having aggregate shaft horsepower equivalent to 5% of DWT tons of tanker (*6,250 hp for 125,000 dwt*)

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Issues with RCW 88.16.190

OPA 90 does not require escort of double-hull tankers;
These vessels are subject only to RCW 88.16.190.

1. Is RCW 88.16.190 a reasonable requirement for double-hull tankers with redundant systems (twin-screw, twin-rudder)?
2. Is the 5% rule for tug horsepower reasonable?
3. Is a performance requirement needed, based on transit speed, etc.?
4. Is a tug capability requirement needed (single screw, twin screw, tractor).?

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OPA 90

Performance requirements for escort vessels :

a) An operational requirement
   - operate within the performance capabilities of its escorts
   - taking into consideration its speed, ambient sea & weather conditions
   - all factors that may reduce the available sea room

b) A set of minimum performance requirements :
   - Towing;
   - Stopping; suspended (OPA 90 does NOT have a minimum braking performance requirement for an escort tug)
   - Holding; and
   - Turning.

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Basis for Acceptable Risk

Proposal Concept

- Single-screw single-hull 125,000 dwt tanker
(significant probability of oil outflow in the event of a grounding)

Revised Basis

- Single-screw IMO minimum double-hull 125,000 dwt tanker
(125,000 dwt hull-tankers do not currently exist and not likely to be built)

Further revised

- Single-screw IMO minimum double-hull Suezmax 150,000 dwt tanker laden to 125,000 dwt for Puget Sound
(these will be the most likely non-TAPS trade tankers coming into Puget Sound)

Additional Tankers Studied

- Polar Millennium Class 142,000 dwt redundant-system double-hull loaded to 125,000 dwt for Puget Sound
- ATC Alaska Class 185,000 dwt redundant-system double-hull loaded to 125,000 dwt for Puget Sound

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Draft Recommendations

The analysis contained in this study does not quantitatively show that the standard of safety proposed by the Washington State Department of Ecology for this study can be maintained if the requirement for tug escorts for redundant-system tankers is eliminated in the waters of Puget Sound currently subject to escort.

The authors of this study do not at this time recommend changes to RCW 88.16.190 that would eliminate escorts for redundant-system double-hull tankers.

The difference in risk of oil outflow between escorted single-screw tankers and non-escorted redundant-system tankers can only be identified by a comprehensive human factors analysis.

It is the recommendation of the authors of this report that a decision for or against the elimination of tug escort for redundant system tankers can only be made if a human factors study is undertaken.

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Draft Recommendations - Findings

Finding – Redundant-system tankers can maintain exceptional control even with the loss of one steering system or one propulsion system. It can be demonstrated that if these vessels are operating in their fully redundant mode and there is a single-system failure (steering or propulsion) in severe wind and wave conditions typical for Puget Sound, there is a high probability that a grounding can be averted.

Finding - A redundant-system tanker with the failure of both propulsion systems or both steering systems cannot be expected to be able to avert grounding without tug escort.

Finding - The incident rate for multiple system failures is several orders of magnitude less than for a single system failure.

Finding - The complete mechanical loss of control of a redundant system tanker (without tug intervention) is an extremely rare event. It is estimated in this study to be in the range of 0.4 to 1 x 10^{-6} (0.4 to 1 in 1,000,000 transits).

this range will be checked and also calculated in terms of year intervals

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Other concerns with RCW 88.16.190

Finding - It is the conclusion of the authors of this study that standing alone, the requirements in state law RCW 88.16.190 are inadequate to ensure a tug escort which can reasonably be expected to avert a tanker grounding in the event of a propulsion or steering failure.

It is voluntary compliance with the Puget Sound Harbor Safety and Security Committee (PSHSSC) “Harbor Safety Plan” of August 1, 2003 that provides this standard.

Other concerns with RCW 88.16.190

Finding – The tanker transit speed is not limited by Washington State law. Tanker speed is limited by voluntary compliance with the PSHSSC "Harbor Safety Plan," which stipulates that the tanker may not exceed the service speed of the escort.

It is possible that redundant-system tankers without escort will choose to increase transit speeds based on other factors. Increasing speed may result in an increased probability of oil outflow from other accidents such as collisions and propelled groundings.

The evaluation of tanker speed limits requires further study.

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Other concerns with RCW 88.16.190

Finding: - Changes in tanker escort will affect the composition of available tugs in Puget Sound.

The change from OPA 90 requirement of two tug escort for single-hull tankers to the RCW requirement of one tug escort for double-hull tankers is already reducing the demand for tugs.

Elimination of tug escort for redundant system ships (which are projected to be able to handle one-half of Puget Sound refining capacity) may eventually result in the highly capable and expensive escort tugs moving to other locations having higher revenue potential.

In the final report ilt will be added that a change in the composition of available tugs will have an impact on participation in ITOS

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Other concerns with RCW 88.16.190

Finding - ~~The authors of this study propose that the federal 125,000 dwt limit for tankers entering Puget Sound may not minimize risk in the event of a grounding~~.

The authors of this study question whether the Federal 125,000 dwt limit for tankers entering Puget Sound minimizes risk in the event of a grounding.

The relative risks of oil outflow from more frequent transits of deadweight limited double-hull tankers should be compared to less frequent transits of double-hull tankers fully laden tankers.

The evaluation of tanker deadweight limits requires further study.

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Discussion of Findings

6. Discussion of Findings
   - Current Practice
   - Incident Probabilities
   - Human factors in Tug Escort Emergency Response
   - Additional Services of Escort Tugs; Auxiliary Bridge, Scouting, Firefighting
   - Oil Outflow and loading to 125,000 dwt (Colin Moore)
   - Risk Introduced by Escort Tugs

Current Practice - Survey

1. Tug selection:
2. Pre-escort conference:
3. Tethered escorts:
4. Running start:
5. Role of secondary tug in the event of an emergency
6. Transit speeds during escort:
7. Tanker escort in Haro Straits:
8. Issues relating to escort down Puget Sound (to Tacoma):
9. Issues relating to foul weather:
10. Practicing of tug emergency response maneuvers:
11. Escort of tankers other than oil tankers:
12. Escort procedures for partially laden tankers:

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Current Practice - Survey

13. Escort of oil barges:
14. Communication with tugs:
15. Emergency towing:
16. First-response oil spill containment and clean-up:
17. Evolution of escort since OPA 90:
18. Issues relating to double-hull, single-screw tankers:
19. Issues relating to double-hull, twin-screw tankers:

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Puget Sound Harbor Safety & Security Committee Standard of Care

- Collaborate work of public and private maritime stakeholders who make up the Puget Sound Harbor Safety and Security Committee (PSHSCC)
- Contains accepted standards and protocols addressing environmental and operational elements of maritime operations unique to Puget Sound
- Standards of care formalize and document good industry practice, addressing:
  - heavy weather; movement in restricted visibility; anchoring; equipment failures and equivalent levels of safety; tanker escort; underkeel clearance; lightering; towing vessels; direct-drive diesel plants; bridge team management; and plan implementation
- Current revision: August 1, 2003

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ASTM Standards for Escort Tugs

- For use in evaluation and selection of tugs to escort disabled ships in confined waters
- Performance-based analyses to evaluate:
  - control requirements of disabled ship,
  - performance capabilities of escort tugs,
  - navigational limits and fixed obstacles of waterway,
  - ambient conditions (wind & wave) that affect escort response, and
  - maneuvering characteristics of combined disabled ship/escort tug(s)
- Preparation of an escort plan for a given ship in a given waterway; to be consulted in dispatching appropriate escort vessel
- Standardized formats for information presentation and exchange
- Recommendations for training, drills, and equipment inspection

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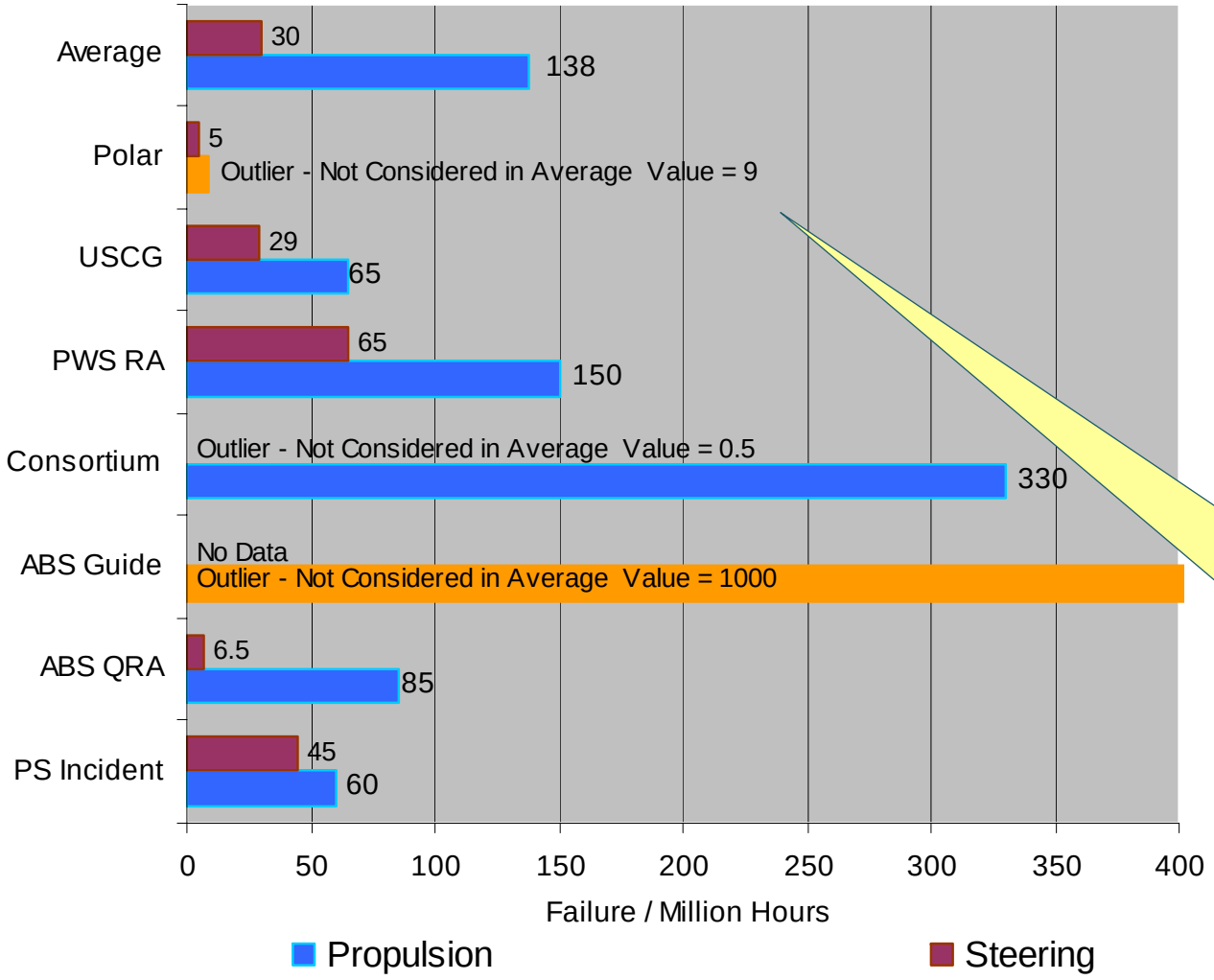
Incident Probabilities



Failures of Propulsion and Steering per million hours of operation

Can be used to calculate probability of failure, grounding, and ultimately the probabilistic oil outflow

Redundant-systems probability = single system probability squared

ConocoPhillips Incident Rates for the Polar Tankers are predictions and thus are not used in the calculations of the range or average rates.

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Value of Prevented Oil Spillage

Socioeconomic costs associated with the spillage of crude oil in the San Juan Islands/Rosario Straits area are estimated to *average* about $1,540 per barrel ($9,700 per cubic meter) of oil spilled

Natural resource damages from a spill in this area are estimated to average $455 per barrel ($2,667 per cubic meter) of oil spilled

Certain spill scenarios (unique combinations of winds, timing of tides, and currents) could more than double these impacts based on the oil trajectory

Reasonably effective on-water oil recovery/removal efforts and protective on-shore/nearshore booming, particularly if initiated in the first few hours after a spill is discovered, could *reduce* socioeconomic and environmental impacts by 25 – 75%.

Modeling of spill scenarios in the San Juan Islands/Rosario Straits area (as well as elsewhere in WA waters) is currently in progress. Results will give a more clear picture of the value of preventing oil outflows of various sizes

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Conditional Probability of Grounding - Channel Width Statistics

Limit:	Zone 2: Rosario Straits		Zone 2a: Guemes Channel		Zone 3: Puget Sound	
	Transfer Distances Measured to 10 Fathom Contour		Transfer Distances Measured to 5 Fathom Contour		Transfer Distances Measured to 10 Fathom Contour	
	(feet)	(n.m.)	(feet)	(n.m.)	(feet)	(n.m.)
Maximum	108,750	17.90	16,680	2.75	36,010	5.93
Average	11,710	1.93	4,540	0.75	10,560	1.74
Median	9,520	1.57	3,170	0.52	8,800	1.45
80 % Greater than	5,870	0.97	1,590	0.26	6,480	1.07
90 % Greater than	4,730	0.78	1,350	0.22	5,630	0.93
95 % Greater than	3,370	0.55	1,190	0.20	4,890	0.80
98 % Greater than	2,770	0.46	1,120	0.18	4,210	0.69
Minimum	950	0.16	1,060	0.17	3,600	0.59

Channel width statistics have been calculated for waterway between Lawerence Point and March Point via Vendovi Island and Saddle Bags. This data was used in the analysis and will be presented in the report.

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Conditional Probability of Grounding with Escort

Tranist Speed at Time of Rudder Failure [knots]	**Rudder Failure Angle** [deg]	Emergency Response **Maneuver**	**Off-Track Distance**	95th Percentile Grounding Averted		
				Rosario Strait	**Guemes Channel**	**Puget Sound** (Admiralty Inlet to Tacoma)
4	5	ASSIST	720'	**YES**	**YES**	**YES**
4	5	OPPOSE	20'	**YES**	**YES**	**YES**
4	10	ASSIST	700'	**YES**	**YES**	**YES**
4	10	OPPOSE	30'	**YES**	**YES**	**YES**
4	20	ASSIST	660'	**YES**	**YES**	**YES**
4	20	OPPOSE	90'	**YES**	**YES**	**YES**
4	35	ASSIST	600'	**YES**	**YES**	**YES**
4	35	OPPOSE	330'	**YES**	**YES**	**YES**
Solution at 4 knots >>>>>>>>>>>>>>>				**YES**	**YES**	**YES**
5	5	ASSIST	1,160'	**YES**	**YES**	**YES**
5	5	OPPOSE	30'	**YES**	**YES**	**YES**
5	10	ASSIST	1,120'	**YES**	**YES**	**YES**
5	10	OPPOSE	90'	**YES**	**YES**	**YES**
5	20	ASSIST	1,010'	**YES**	**YES**	**YES**
5	20	OPPOSE	580'	**YES**	**YES**	**YES**
5	35	ASSIST	860'	**YES**	**YES**	**YES**
5	35	OPPOSE	2,610'	**YES**	NO	**YES**
Solution at 5 knots >>>>>>>>>>>>>>>				**YES**	**YES**	**YES**
6	5	ASSIST	1,620'	**YES**	NO	**YES**
6	5	OPPOSE	70'	**YES**	**YES**	**YES**
6	10	ASSIST	1,530'	**YES**	NO	**YES**
6	10	OPPOSE	370'	**YES**	**YES**	**YES**
6	20	ASSIST	1,350'	**YES**	NO	**YES**
6	20	OPPOSE	3,550'	NO	NO	**YES**
6	35	ASSIST	1,110'	**YES**	**YES**	**YES**
6	35	OPPOSE	4,710'	NO	NO	**YES**
Solution at 6 knots >>>>>>>>>>>>>>>				**YES**	**NO**	**YES**

Tranist Speed at Time of Rudder Failure [knots]	**Rudder Failure Angle** [deg]	Emergency Response **Maneuver**	**Off-Track Distance**	95th Percentile Grounding Averted		
				Rosario Strait	**Guemes Channel**	**Puget Sound** (Admiralty Inlet to Tacoma)
8	5	ASSIST	2,450'	**YES**	NO	**YES**
8	5	OPPOSE	630'	**YES**	**YES**	**YES**
8	10	ASSIST	2,280'	**YES**	NO	**YES**
8	10	OPPOSE	5,580'	NO	NO	NO
8	20	ASSIST	1,940'	**YES**	NO	**YES**
8	20	OPPOSE	7,700'	NO	NO	NO
8	35	ASSIST	1,560'	**YES**	NO	**YES**
8	35	OPPOSE	5,680'	NO	NO	NO
Solution at 8 knots >>>>>>>>>>>>>>>				**YES**	**NO**	**YES**
10	5	ASSIST	3,220'	**YES**	NO	**YES**
10	5	OPPOSE	7,030'	NO	NO	NO
10	10	ASSIST	2,920'	**YES**	NO	**YES**
10	10	OPPOSE	8,940'	NO	NO	NO
10	20	ASSIST	2,420'	**YES**	NO	**YES**
10	20	OPPOSE	8,290'	NO	NO	NO
10	35	ASSIST	1,920'	**YES**	NO	**YES**
10	35	OPPOSE	5,900'	NO	NO	NO
Solution at 10 knots >>>>>>>>>>>>>>>				**YES**	**NO**	**YES**
12	5	ASSIST	3,860'	NO	NO	**YES**
12	5	OPPOSE	9,370'	NO	NO	NO
12	10	ASSIST	3,420'	NO	NO	**YES**
12	10	OPPOSE	9,410'	NO	NO	NO
12	20	ASSIST	2,790'	**YES**	NO	**YES**
12	20	OPPOSE	8,210'	NO	NO	NO
12	35	ASSIST	2,210'	**YES**	NO	**YES**
12	35	OPPOSE	5,940'	NO	NO	NO
Solution at 12 knots >>>>>>>>>>>>>>>				**NO**	**NO**	**YES**

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Preliminary Conclusions - Revisited

The Probability of Oil Outflow for Redundant System Double Hull Tankers without Escort

is not known with respect to

The Probability of Oil Outflow for Single Screw Double Hull Tankers with Escort

Human factor error rates can not at this time be answered quantitatively.

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Human Factors

- Initial recognition that something is wrong
  - Engine Failure
  - Rudder Failure
- Communication of failure recognition to Master, Officer of the Watch, Pilot, etc.
- Diagnose failure
- Check navigational position
- Determine on-board corrective maneuver
  - Shutdown propulsion if rudder failure
  - Order course to be steered if engine failure
- Determine and Order on-board repair response
- Determine if tug assistance will be required
  - Call for tug assistance (if required)
- Determine which corrective maneuver is required
  - retard (stop ship)
  - assist (U-turn)
  - oppose (restore heading)
- Inform tug of chosen maneuver
- Arouse crew to handle tug lines (if required)

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Human Factors (cont.)

ON TUG

- Take pilot's call
- Sound alarm / alert crew
- Check navigational position, Check position wrt tanker
- Determine course to ordered position
- Quick check of systems (engine, winch etc.)
- Crew preparation / prepare lines
- Maneuver tug into position
- Pass lines
- Make fast lines (On Tanker / On Tug)
- Clear aft deck
- Maneuver tug into position to apply corrective forces
- Maximize corrective forces
- Hold position throughout maneuver
- Change positions if required or ordered
- Ease forces so as to not overcorrect
- Prepare for rescue tow if required

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Additional Escort Tug Services

Redundant lookout and awareness

- physically distributed perspectives
- situation awareness
- hazard avoidance
- vessel positioning

Command and control decision making

Emergency response capabilities

Redundant Organizational Structure

Firefighting

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Oil Outflow Methodology and Findings

Presentation by Colin Moore, Ph.D.

Herbert Engineering Corporation

Risk Introduced by Escort Tugs

Accidents involving tanker and escort tug:

Year	Where	Tug (Tanker) Involved	Brief Description of Accident
?	San Francisco Bay	?	Collision between tug on autopilot and escorted tanker, during tanker turn
1998	Prince William Sound (Port Valdez)	Sea Voyager (ARCO Spirit)	During routine escort, tethered tug bumped at the stern by an escort response vessel (Freedom Service); tug in turn struck stern of tanker. Minor damage to all three vessels. No injuries; no oil discharged.
2002	Puget Sound (Between Buoy R. & Davidson Rock)	Sea King (Allegiance)	Tug run down by tanker during running start. Tug capsized and then righted itself, suffering significant damage. Tanker also damaged; took on water, but no danger of sinking.

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Recommendations for Further Study

- Thorough examination of human factors associated with single-screw escorted tankers and twin-screw unescorted tankers
  - Analysis of human and automated tasks, to provide baseline
  - Historical system benchmarking
  - Dynamic modeling of risk in system
  - Assessing human and organizational error
- Examination of tanker speed limits
- Examination of tanker deadweight limits

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Presentation of Final Report

Study of Tug Escorts in Puget Sound

Prepared for State of Washington: Department of Ecology
Lacey, Washington

Prepared by
The Glosten Associates, Inc.
in collaboration with
Herbert Engineering Corporation
Professor Martha Grabowski, Ph.D.
Environmental Research Consulting

Glosten File No. 04075
December, 2004